COMMENTARY

Editors note: This commentary is part of a series initially presented at the Waste/Economies/Ecology hybrid international symposium at the Institute for Culture and Society at Western Sydney University, Australia in February 2023. The symposium was part of the research project ‘Investigating Innovative Waste Economies: Redrawing the Circular Economy’ funded by the Australian Research Council. The symposium brought together academics and artists from around the world who are thinking with waste to enable novel response to its ethical and political challenges. We thank all our contributors to this special commentary section for their participation and thinking.

How to be tidal: designing with waste streams as matter in flow and matter of value

Dr Kate Scardifield
Material Ecologies Design Lab, Faculty of Design, Architecture and Building, University of Technology Sydney. Australia.
Katherine.Scardifield@uts.edu.au (corresponding author)

Nahum McLean
Material Ecologies Design Lab, Faculty of Design, Architecture and Building, University of Technology Sydney. Australia.
Nahum.McLean@uts.edu.au

ORCIDs
Kate Scardifield: 0000-0002-4112-2376
Nahum McLean: 0009-0003-1766-3548

I wasn’t prepared for the smells. It was an array of foul and rotting smells, the kind that get up into your nose, peppered with salt and steeped in brine. These olfactory lessons occurred between October 2021 and January 2022 when Nahum and I processed over a tonne of wet, fermenting seaweed ~~,~~ and scrubbed, cleaned, and sun-~~-~~bleached over a tonne of oyster shells. If we had known the extent of the dirty, sweaty, and grimy work from the beginning, I'm unsure whether we would have committed to it from the outset. ~~It was dirty, sweaty, and grimy work, that had I known the extent of from the beginning I’m unsure I would have committed to from the outset.~~ But curiosity coupled with naivety can be a powerful gift, and sometimes the best work artists and designers can do is to *simulate*. By acting out new systems and trialling different ways of making, creative practices can be put to use in modelling radical types of change yet to come into fruition. The change we are committed to is the transition from fossil derived materials and their fossil reliant systems~~,~~ towards sustainable biogenic alternatives. Such alternatives can arise from ~~Specifically, it is in~~ the development of biomaterials and bio-based products that ~~can~~ utilise residual organic waste through a biorefinery framework, helping to capture and store another form of waste in the process:~~;~~ atmospheric carbon dioxide ($C0_2$).

This article details our experiences designing with waste and the development of new materials from two aquaculture waste streams~~-~~ —a residual seaweed biomass that’s been cultivated to treat wastewater, and oyster shell waste sourced from a co-operative of farms and estuaries along the NSW coast. It offers insights into some of the inherent value systems (or lack thereof~~ of~~) that are attached to organic matter outputs ~~,~~and what effect these inheritances can have when building a shared understanding between stakeholders of the potential for waste to matter as matter.~~, then of its possibilities to transform.~~

We need to be thinking through waste, not just about it:~~.~~ o~~O~~bserving its tidal ebbs, travelling in its streams and flows, and following its leaks and spills. Like Melody Jue, who understands that coming to know the ocean occurs through 'accumulated moments of contact' (Jue 2020, 3), in order to subvert the hyperobjectivity of waste we must allow for embodied sensing to occur. Our thinking ~~I'm trying to think~~ here comes from a vibrant matter perspective, the kind that Jane Bennett puts forward in her political ecology of things (2010). Matter that is~~'s~~ cycled through ingesting, excreting, and metabolising for growth (of a body, a city, a society) is in constant flow- ~~,~~as waste or not~~,~~ and it persists with indifference. It is~~t's~~ this becoming of something else (whether we want it to or not) that requires our attention, and we'd do ourselves a favour to tune into its rhythm.

How are we going to live with the weight our emissions? To do so, we have to build differently. ~~In this instance~~ O~~o~~ur research is engaged in an onerous–and odorous–task where design isn't constrained to *designing* a product;~~,~~ it extends to thinking through adaptions of manufacturing processes, supply chains, and systems of production. How we come to arrive at the materialisation of a thing is far from concrete, let alone straightforward. Carbon Dioxide (CO_2) is an insidious and notoriously invisible thing. The main contributor to global warming is a colourless and often odourless greenhouse gas that is clogging the E~~e~~arth's atmosphere. It is an~~An~~ ungraspable hyperobject (Morton 2013) that's most commonly understood via its 'footprint'. You may recall visualisations of CO_2 often take the form of light, hazy blue bubbles or spheres hovering above houses or over whole continents, even appearing to float across or through a cityscape. Awakening to our climate crisis is suspended here in a state of graphic apathy. These images lend themselves to what Jenny Offill (2020) describes as 'twilight knowing', where atmospheric carbon is all around us, rapidly ballooning in volume and measured in metric tonnes, as we await ~~we're awaiting~~ its disastrous impact.

We need to capture atmospheric carbon, sink this into something, and then put this somewhere for a long period of time. The average Australian home is estimated to last over 60 years, and in some instances up to 150 years. The crucial factors contributing to its longevity are often cited as the materials used, the quality of workmanship, its ability to receive ongoing maintenance, and the weather (Property Registry Team 2019). In 27 years the global population is set to reach 9.8 billion, and up to 90% of the buildings we will inhabit already exist today. Currently the building and construction sector accounts for 40% of CO_2 emissions globally and most building materials continue to be made from non-renewable resources using extractive and energy intensive processes (GlobalABC, IEA, and UNEP 2019). There is very little time left and a lot to do to reduce Green House Gas (GHG) impacts *and* develop significantly more sustainable construction materials that can help with repairing and retro~~-~~fitting existing building stock.

Working out how to make strong, stable materials from biogenic waste streams can mitigate a few of these rather complex problems. They won't solve them, but they can make a substantial contribution towards lowering the emissions of the construction sector~~,~~ helping to retrofit and repair our buildings and our homes, all whilst providing storage solutions for $C0_2$. The trick is to stop seeing residual biomass as compostable waste and to start understanding it as vital matter that *matters*. To borrow from Donna Haraway, ‘it matters what matters we use to think other matters with’ (Haraway 2012, 12). We have tried to think through aquaculture waste by experiencing its affects, unique characteristics, and affordances with our bodies in order to go beyond a capitalist economic framework where valorising waste is predicated on establishing a profit margin. To *matter* is to mean something, and this meaning can’t be reduced to an economic value-add in resources because waste is matter that drifts and persists across social, environmental, and ethical spheres. Whilst not intended as a phenomenological study, the act of designing and making in this instance meant that waste was impressed on and pushed up against us throughout the process. With it came swathes of sensory information, material feedback and a growing awareness of other stories and ways to think through the ebbs and flows of matter and its tides.

Algae (microalgae and macroalgae) has the incredible ability to ingest carbon dioxide (CO_2) and expel oxygen. Marine macroalgae (seaweed) thrives in water rich with nitrogen and heavy metals, photosynthesising and growing exponentially in these conditions. Seaweed farming is well established globally, albeit not evenly distributed around the globe.~~,~~ S~~and~~ ~~s~~eaweeds are cultivated for a range of economic purposes from food and fuel to animal feed, and at a molecular level its compounds are regularly utilised in pharmaceuticals, nutraceuticals, and as a feedstock alternative to the petrochemicals commonly used in plastics. In Australia, seaweed is being grown to remediate wastewater; currently this practice is predominantly attached to inland aquaculture and fisheries, but this scalable and adaptable biotechnology has the potential to grow ~~(excuse the pun)~~ exponentially in the coming years as we grapple with population growth, the growing demand for food security, and the need to establish more sustainable farming practices. Where this is occurring as part of a biorefinery framework, the seaweed grows while filtering wastewater.~~,~~ I~~i~~t i~~'~~s then harvested and pressed to extract value-added compounds, and the residual biomass left over is treated as a waste by-product. If that’s left to compost and breakdown, it releases the $C0_2$ it has~~’s~~ stored back into the atmosphere.

Oysters themselves are their own marine environment. They are bivalves that filter water and ~~,~~ provide substrate and surface for epiphytic growth.~~;~~ T~~t~~hey are houses for other living organisms, including mussels, other oysters, fish, algae and a variety of other aquatic invertebrates. Their very existence, including their decomposition, is crucial in promoting biodiversity across a range of marine habitats. F~~and f~~or a millennia, they have been an abundant food source carefully managed by Traditional Owners. Since colonisation, Australia has decimated its native oyster population. We have gone from rich and abundant natural oyster reefs all along our coastlines~~,~~ to dredged waterways and harbours that have been gutted and stripped of these crucial intertidal habitats. Many of those shells are in our buildings. Fragments of oysters can be found in the mortar of some of Sydney’s earliest colonial architecture. They were excavated from middens and burnt for their lime, like those that towered 10-12 metres high at Tubowgule/Bennelong Point. Middens themselves are a form of sustainable architecture. They mark ancient meeting places for Aboriginal people and their sheer scale is testament to the careful management of oyster populations that was possible up to the arrival of the British.

During our~~my~~ early encounters with the Greenwell Point oyster farms located on Jerrinja Country in the Shoalhaven, we~~I~~ noticed mounds of empty shells~~,~~ some laying behind the back of sheds, others partly spilling out from catch baskets. There were also piles dotted along the roadside and mounds crushed almost to a fine powder that had been used to fill potholes in the road (Fig. 1). Through conversations with the farmers, we~~I~~ started to learn that a lot of these piles weren't just dumped refuse like ~~I'd~~ first assumed;~~,~~ instead, they were slowly being cycled through the farm and the river in various ways. Often the shells were left in the shallows of the estuary for tiny fish and various other marine creatures to pick over or deposited back into deeper parts of the waterway to encourage various alga to take hold. There is a complex feeding and composting cycle going on that's designed for the ongoing maintenance of the waterways, and that's not easily divisible into industry and environment. It was a reminder that, as designers, it matters where we situate our engagement with organic waste matter~~,~~ and with what waste streams we choose to intervene. There are systems of circularity that aren't always apparent and other more than human rhythms of mattering at play.

Fig. 1: Oyster shells used to fill potholes, Jerringa Country, Greenwell Point, Shoalhaven, NSW.

Biogenic waste matter is (of course) a home for other living organisms. Eventually you get used to the smell when you're scrubbing and cleaning oyster shells in the sun, but then come the maggots and the flies. Understanding and appreciating their role in the breakdown of organic matter is easier said than done when you are waist deep in oyster effluent, and you smell like a barge. The flies became unexpected but important collaborators on the project. They helped us to identify which shells had slipped through the cleaning process either still containing oyster tissue, or those with juvenile oysters (termed sprat) that had grafted and grown onto an older shell. It became quicker and easier to pick over and manually sort hundreds of kilos of shells basking in the sun thanks to the flies (Fig. 2). Go where they go, and you'll find fouling.

Fig 2. Picking and sorting with the flies Photo: Kate Scardifield.

There were distinct differences between batches of shell waste depending on our points of collection. A shift in waste classification also became apparent between what was sourced from the farm and what was collected in the city from food handlers. The oyster shell waste was sourced in two stages. During the first stage, 500~~-~~kg of shells, a mixture of Pacific and Sydney Rock oysters~~,~~ were acquired from a commercial dispatch centre in the south of Sydney, where the oysters were being cleaned, sorted, and shucked ready for sale in supermarkets and at other various food retail outlets. This meant our first batch of shells were predominantly oyster shell lids (the flat part of the shell) and a waste by-product from the food industry that would have otherwise ended up in landfill (Fig. 3). Upon dispatch from the farm, the oyster (including the shell part we don't eat) goes from a bivalve to a food item. This meant specific food hygiene protocols then needed to be observed and we weren't able to collect from this source again as there was a potential for it to breach their safe waste disposal compliance. In the second stage, around 600~~-~~kg of oyster shells was sourced directly from the farms, which meant that there were significantly more oyster cups than lids (the rounded part of the shell). These shells then required a different system to be developed for washing and cleaning, largely in part due to their shape, but also due to their significantly different condition of biofouling than those that came from the dispatch centre.

Fig 3. Shell waste bound for landfill. Photo: Kate Scardifield

Once the shells w~~h~~ere clean and dried, they were mechanically broken down using a rammer compactor~~,~~ before being manually sieved and graded. At the completion of the project, we had processed over 1000~~-~~kg of shell waste. Had we attempted to do this project only twelve~~12~~ months later, it would not have been possible. The extreme weather that battered the NSW and east coast of Australia in 2022 –~~,~~ particularly the rain and flooding of the region – led to disastrous oyster farming season. ~~,~~ M~~m~~any of the farms at Greenwell Point were only able to open for a handful of days in the past year.

The seaweed waste was not without its own difficulties. This residual biomass was coming from an inland fisheries farm in northern Queensland, which meant interstate road transportation ~~. Firstly,~~ from farm into Townsville then Townsville to Brisbane, followed by Brisbane to Sydney, then Sydney to our specified delivery point. Interstate freight and delivery systems still struggling under the ongoing effects of the pandemic meant a $1m^3$ container (IBC) could be in transit anywhere between seven~~7~~ days and a few weeks. Without ~~being able to have~~ direct oversight of dispatch or any ability to control the goods at transfer points, ~~this meant~~ the containers could be left exposed to the weather, out in the sun and heat for hours or even days at a time. We could never be entirely sure of the state the waste material would arrive in. Our first load (around 400kg) had a thick layer of fouling where the seaweed had fermented and begun to congeal (Fig. 4). Whilst technically still useable, the sulphurous, rotting smell made it near impossible to work with because of the manual decanting of the biomass and all the manual mixing and handling involved. We received another IBC just before Christmas in 2021 ~~-~~which contained around 400kg of dried seaweed waste. This batch was littered with soil, dirt, and bits of dried grass indicating ~~it's likely~~ that it had likely been tossed out onto a paddock or similar and left to compost. The container went missing in transport and took two weeks to arrive. Upon opening we discovered a spider infestation (the horror) and rushed to bag and freeze the material in order to remove the arachnid interlopers. This wasn't waste to the spiders; it was a habitat – a~~. A~~ site of nutrients with~~,~~ the right kind of temperate atmosphere and weather conditions optimal for a spider city to be born. Our horror was their haven.

Transporting organic waste over long distances is not ideal. In fact, it creates a range of issues that require considerable labour, energy, time, and costs to resolve. This is before the waste material can even be prepped to use. Any increases to the scale of production would further exacerbate this. The energy expenditure required for refrigerated transport (to reduce the likely hood of fouling or incubating other organisms) coupled with high fuel costs indicates this is not a sustainable solution for waste procurement. Establishing a more localised system or source is necessary, and if this is not possible, the integration of additional steps that broaden the biorefinery framework is needed to prepare the residual biomass on site. To get the waste from a farm in northern Queensland to the basement of a university building in the middle of the Sydney CBD required substantial planning and logistics management. Nobody really could believe we wanted to move it. We were liaising with technical officers who were collecting the seaweed waste at the fisheries farm, as well as interstate freight transport managers to work through and resolve a wide range of issues that arose with transit and procurement. The condition of the waste (it's level of fouling) determined our ability to work it, so from our perspective we greatly valued its condition. The stakes were high. We needed to describe and continue to reiterate, in a clear but compelling way, why keeping the seaweed waste cold and fresh was important. Asking companies to value their waste where it has zero product value is a hard sell. Particularly when it adds to the labour or workload of individuals operating within existing industrialised systems focused on the production and supply of other things. When the 'product' is something else, understanding and being willing to care for what *isn't* the product requires believing (or suspending disbelief) in the transformative possibilities of that waste and its potential for metamorphosis. This was particularly the case in the nascent stages of our material testing and experimentation when many things didn't work, you're asking for more residual waste to be shipped, and there aren't any successful or fully formed material prototypes that can be shared with industry partners, which can spark enthusiasm and ongoing support. The value-add proposition we offered in this instance was using waste to make art. This meant clearly demonstrating the socioeconomic benefits that can be generated through artistic endeavour and making visible other cultural forms of capital to stakeholders.

Fig 4. A damaged IBC containing 400kg of seaweed waste. Photo: Kate Scardifield

Without wanting to focus too much on the product (or art object) which is not the point of this paper, it's worth shedding some light on the multifaceted role creative practice can play in transitioning our perceptions of waste, adding value to it, and aestheticising it in ways that build acceptance, interest, and the desire for new biogenic types of materials. In the early months of 2022, we pressed and cured over 100 ~~bio-~~bricks, transforming two~~2~~ tonnes of organic aquaculture waste into solid, strong, and stable masonry pieces (Fig. 5 and Fig. 6). The ~~bio-~~bricks built a freestanding column measuring 90 cm in diameter and close to 3 meters high (Fig. 7). The project was undertaken with scientists from the Climate Change Cluster (C3) at the University of Technology Sydney, and with industry support from Pacific Bio Australia and Australia's Oyster Coast. It was presented at the Art Gallery of South Australia as part of the 2022 Adelaide Biennial of Australian Art, showcasing an architectural application for these waste streams and their potential for use in building and construction.

The column's fluted design references the architecture of classical columns, historically rendered in marble and stone, that hold up the porticos and the external facades of some of the world's most prominent civic and government buildings. People who have encountered the column or the ~~bio-~~bricks in other exhibition contexts often comment on their scent first– they smell somewhat like the sea. Rachel Cusk (2022) has written about the survival of human gesture and artistry as being bound to the ability of materials to survive. If we think about materials weathering under external forces—colonial, social, political–and confronting the weather itself, then matter can never be fixed. As Tim Ingold (2012) has argued, form is ever emergent as matter is *always* variable. What he characterises as 'its tensions and elasticities, lines of flow and resistances' (p.433) are much like tidal currents that govern bodies of water and the rising and falling of the sea. Our ~~bio-~~bricks are therefore somewhat misleading. Their aesthetic formalism and contained appearance as an interlocking structure somewhat denies the processes of their making. They were slumpy, mushy, sagging, and much more akin to leaky things (Ingold 2012). They would crack and crumble; overnight they would become a substrate for growth with soft white mould appearing in their crevices. Responding to moisture in the atmosphere they would soften and bend ever so slightly under their own weight.

To produce the ~~bio-~~bricks we utilised a cement mixer, a commercial food processor, an industrial hammer mill, a plate compactor, and a commercial dehumidifier, but even then, transforming two ~~2~~ tonnes of aquatic waste matter relied largely on long bouts of full body exertion and manual labour. We had a rotating group of 10 project assistants who worked with us washing, cleaning, preparing and mixing materials, as well as packing moulds and pressing out over 100 brick pieces. This was dirty and sweaty work that coincided with some of the most disastrous flooding events ever recorded by the Australian Bureau of Meteorology. This too is tidal phenomena, uncontrollable and governed by external forces. The east coast of NSW was inundated with rain over the summer months in 2021 and early 2022, and curing the bricks in hot, wet, and humid conditions was arguably the project's biggest challenge. We wanted and needed the *opposite* conditions to what the weather was doing, so we took to building a temporary environmental chamber and for around two weeks we tended a small sealed room within a room. A chamber of scent! A repository of briny and fermenting smells that stayed in our clothes and in our hair after daily sessions of patiently turning and rotating the bricks so that slowly, all the moisture could be wicked from the centre of each brick and out through its surface, allowing it to harden and stabilise.

Fig 5. Bio-bricks made from aquaculture waste. Photo: Robin Hearfield

Fig 6. Bio-bricks made from aquaculture waste. Photo: Robin Hearfield

Fig 7. Bio-masonry column installed at the Art Gallery of South Australia, 2022. Photo: Saul Steed

Perhaps we need to pay more attention to what Damla Tonuk and Tom Fisher (2020) have called the processuality of materials. To find a 'different way of knowing' their agency, affordances and attitudes means we need to expand our thinking beyond production and consumption cycles. This extends to our encounters with waste if we are to come to know it as matter that persists with indifference and that is made by social, environmental, and ethical relations.

We've reached a tipping point in the climate crisis and getting to net zero isn't going to be enough. The science is very clear that we need to be drawing down CO_2 from the atmosphere and sinking this into something if we are going to have half a chance of staying below 1.5 degrees of global warming. Our options to sink are currently rather limited, and there is an overreliance on carbon offset forestry initiatives tasked to do all this work. Whilst these remain crucial forms of mitigation in both the aquatic and terrestrial spheres, thinking about how we might make materials from carbon rich organic waste matter presents another opportunity to sequester CO_2 into materials that are designed to be long lasting, and that can be taken out of circularity for a while by putting them into buildings. How we go about making them strong and stable enough to be long lasting can't be by creating types of chemical or molecular bonding that means that these new biomaterials can't break down. Bio-based often doesn't mean biodegradable. As a result, there is copious amounts of greenwashing done by companies who offer '~~"~~sustainable'~~"~~ drop-in bio replacements that do nothing to curb overconsumption and throwaway culture (Ginsberg and Chieza 2018). This then poses another pertinent question to ponder as we think through waste matter—how do we manage biodegradability with designing for longevity?

Fluctuations in volumes of biogenic waste matter are inevitable. What is abundant in one season, could be scarce in the next. How do we design with this in mind? If we are going to design with waste in ways that aren't extractive and exploitative, and that don't deplete and decimate biological resources, then *we need to be tidal.* Allowing for ebbs and flows in volume, tolerating times of scarcity and abundance in the supply of organic matter, and changes to that organic matter that can be based on season, weather, and shifts in the environment. Let's all acknowledge that this is a manufacturer's nightmare. There is i~~I~~nconsistency in supply. But if we are going to live with the weight of our emissions and inhabit a built environment that’s helping to store $C0_2$, do we need to adjust our expectations of some of the materials that surround us? We are~~I’m~~ not talking about the performance of construction products or specifically their mechanical properties, but rather their surfaces, their colouration, their acoustic or thermal properties, and their scent.

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Notes on contributors

Dr Kate Scardifield

Dr Kate Scardifield is an artist and Co-Director of the Material Ecologies Design Lab in the Faculty of Design, Architecture and Building at UTS. Her research charts materials through states of transformation, emphasising the importance of transitioning critical systems of production away from petrochemicals and towards more sustainable material futures.

Nahum McLean

Nahum McLean is a PhD candidate and member of the Material Ecologies Design Lab in the Faculty of Design, Architecture and Building at UTS. His research is responding to climate breakdown and developing novel biobased and biodegradable materials for applications across fashion, design and architecture.

Conflict of interest

The authors have no relevant financial or non-financial competing interests to report.